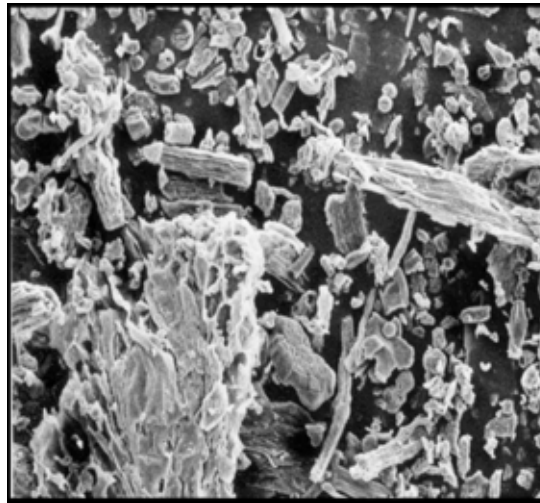


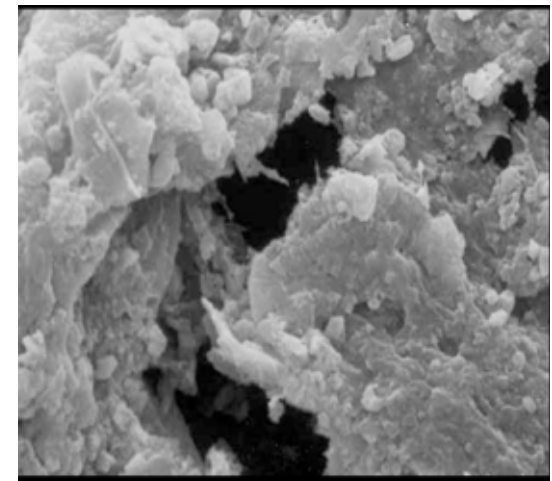
Soil Carbon Sequestration: A Low-Cost, High-Benefit Approach to Climate Change Mitigation



Carbon generation



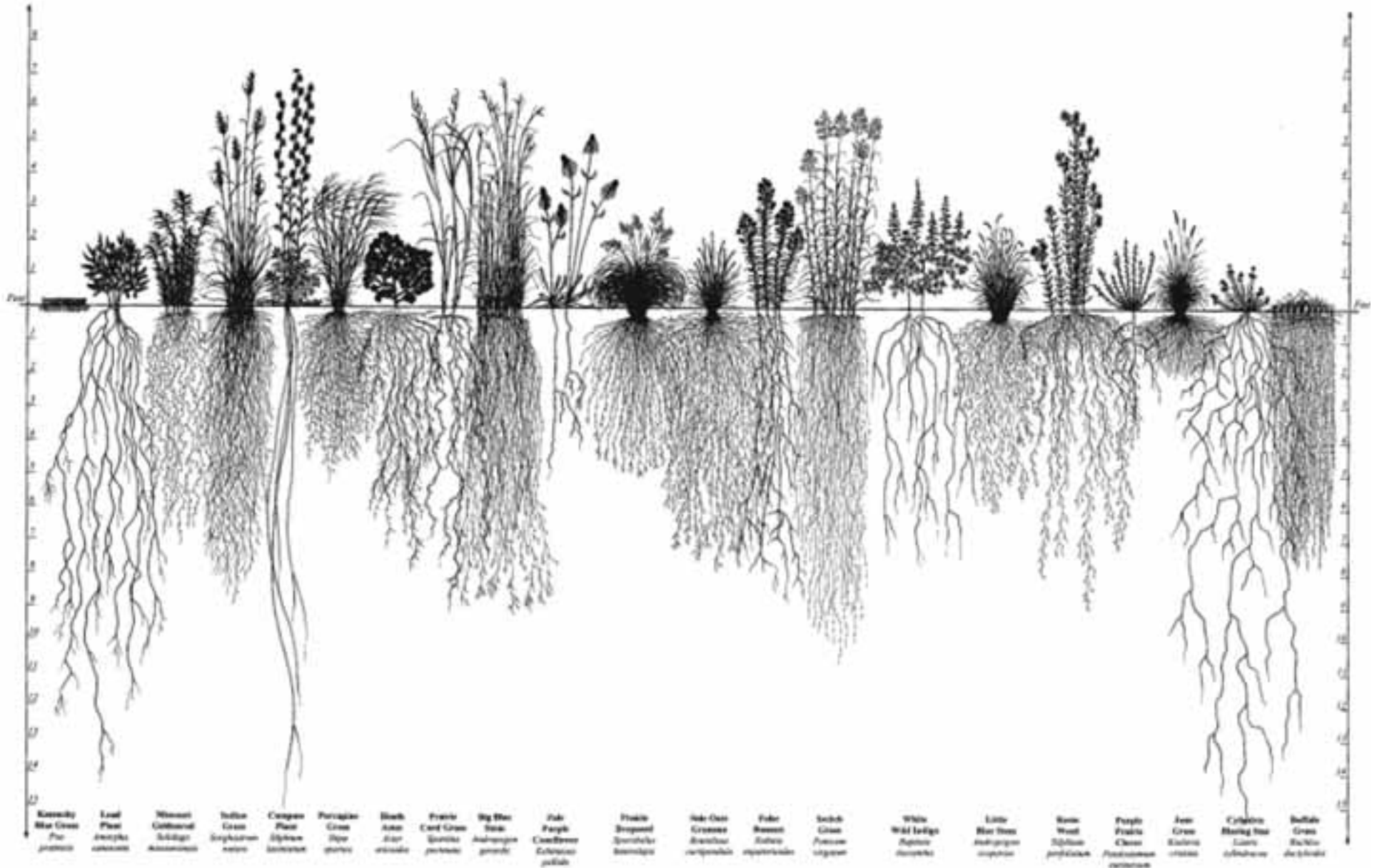
Carbon processing



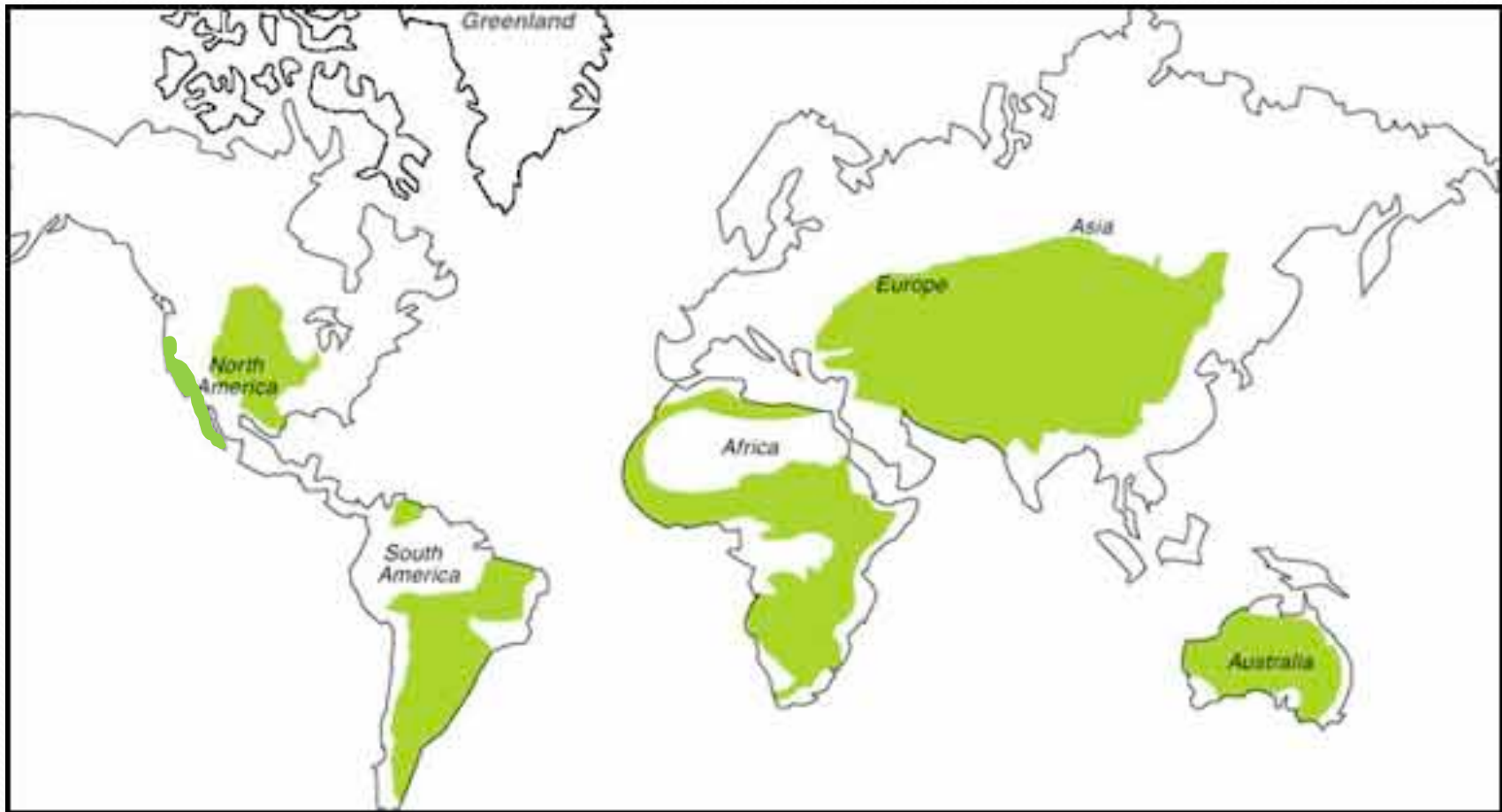
Carbon storage

California Climate Change Research Symposium
Whendee L Silver and Rebecca Ryals
University of California, Berkeley
wsilver@nature.berkeley.edu

Grasses allocate a high proportion of their photosynthate belowground to roots → greater soil carbon pools



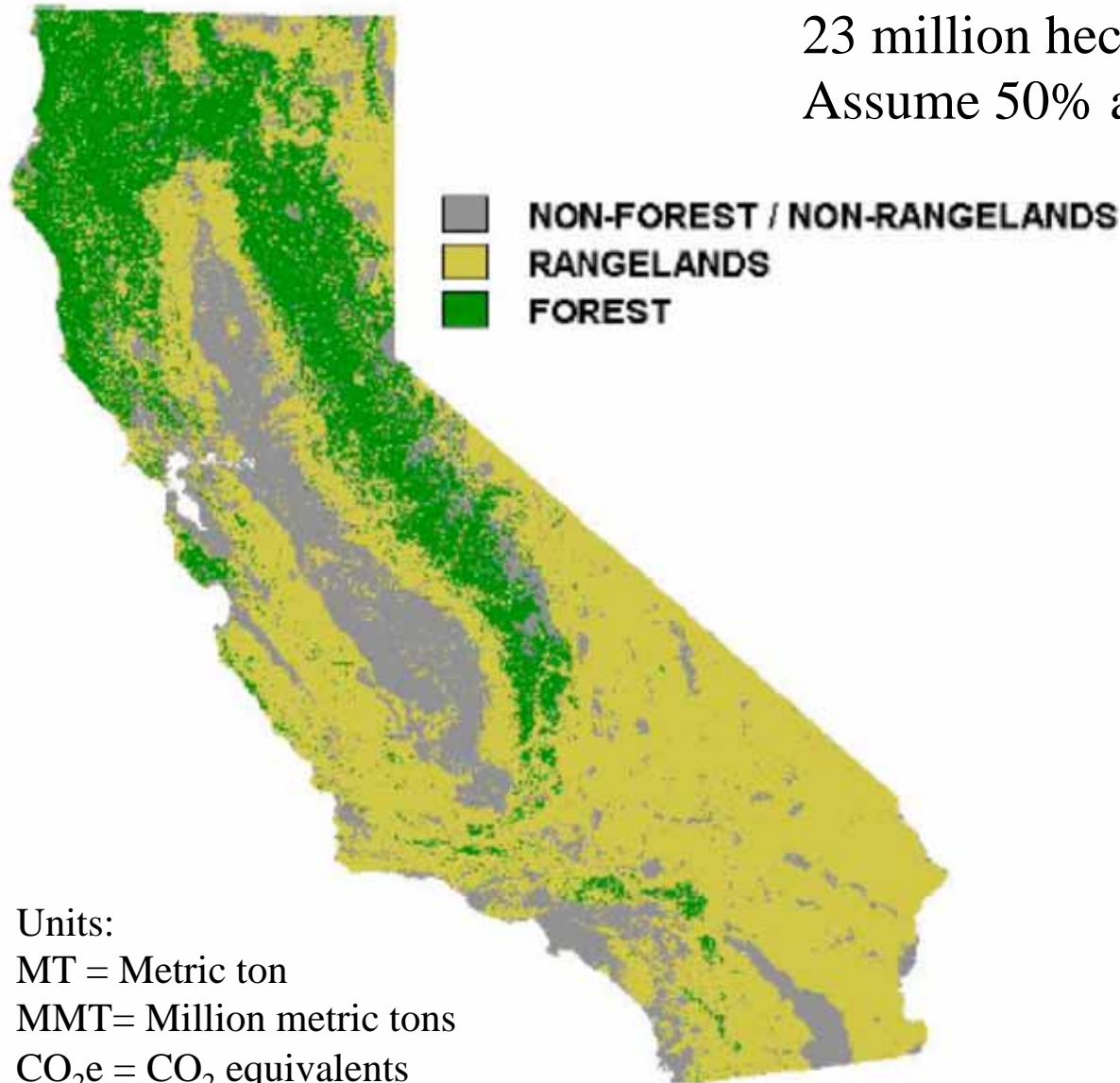
Grasslands cover a significant portion of the Earth's land surface



- *30% of global land surface
- *Over half of the global land use
- *33% of the US land area
- *56% of California land area

California Grasslands and Carbon Sequestration

23 million hectares of rangeland statewide
Assume 50% available for C sequestration



At a rate of $1 \text{ MT C ha}^{-1} \text{ y}^{-1}$
= 42 MMT $\text{CO}_2\text{e/y}$

At a rate of $5 \text{ MT C ha}^{-1} \text{ y}^{-1}$
= 211 MMT $\text{CO}_2\text{e/y}$

Units:

MT = Metric ton

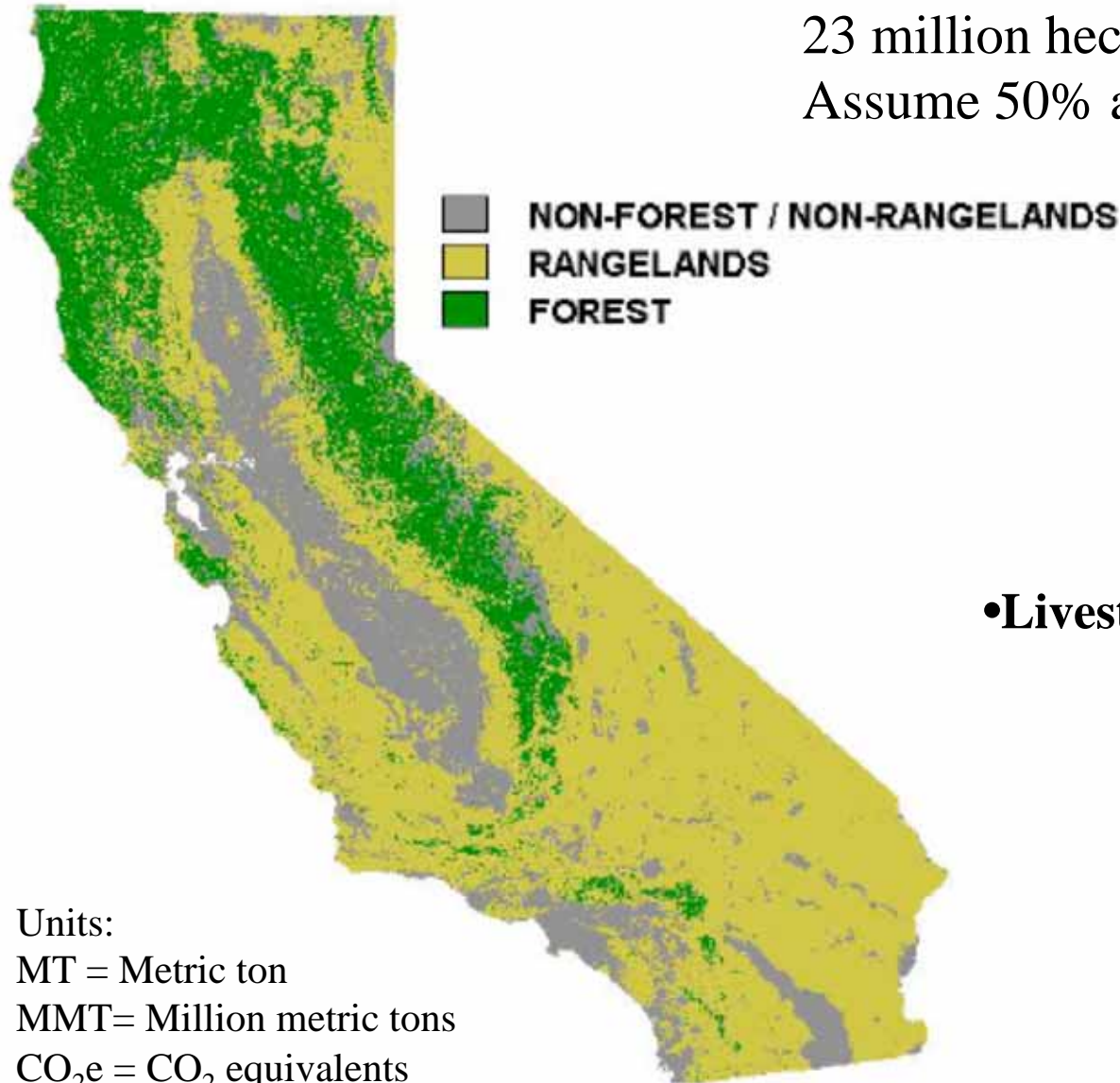
MMT= Million metric tons

CO_2e = CO_2 equivalents

MT=Mg=Metric ton

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• **Livestock ~ 15 MMT CO₂e/y**

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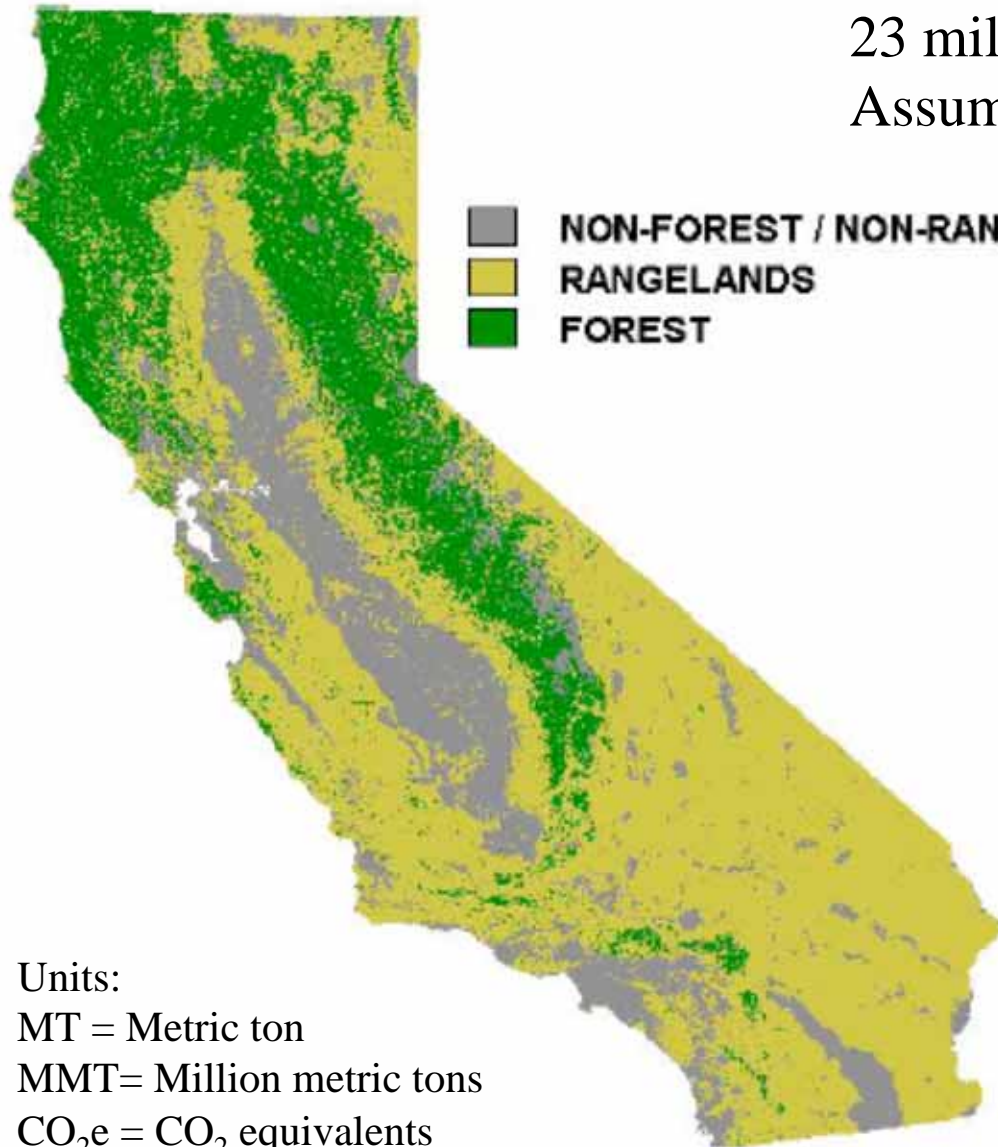
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MT=Mg=Metric ton

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■ NON-FOREST / NON-RANGELANDS
■ RANGELANDS
■ FOREST

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• **Livestock ~ 15 MMT CO₂e/y**

• **Commercial/residential ~ 41 MMT CO₂e/y**

Units:

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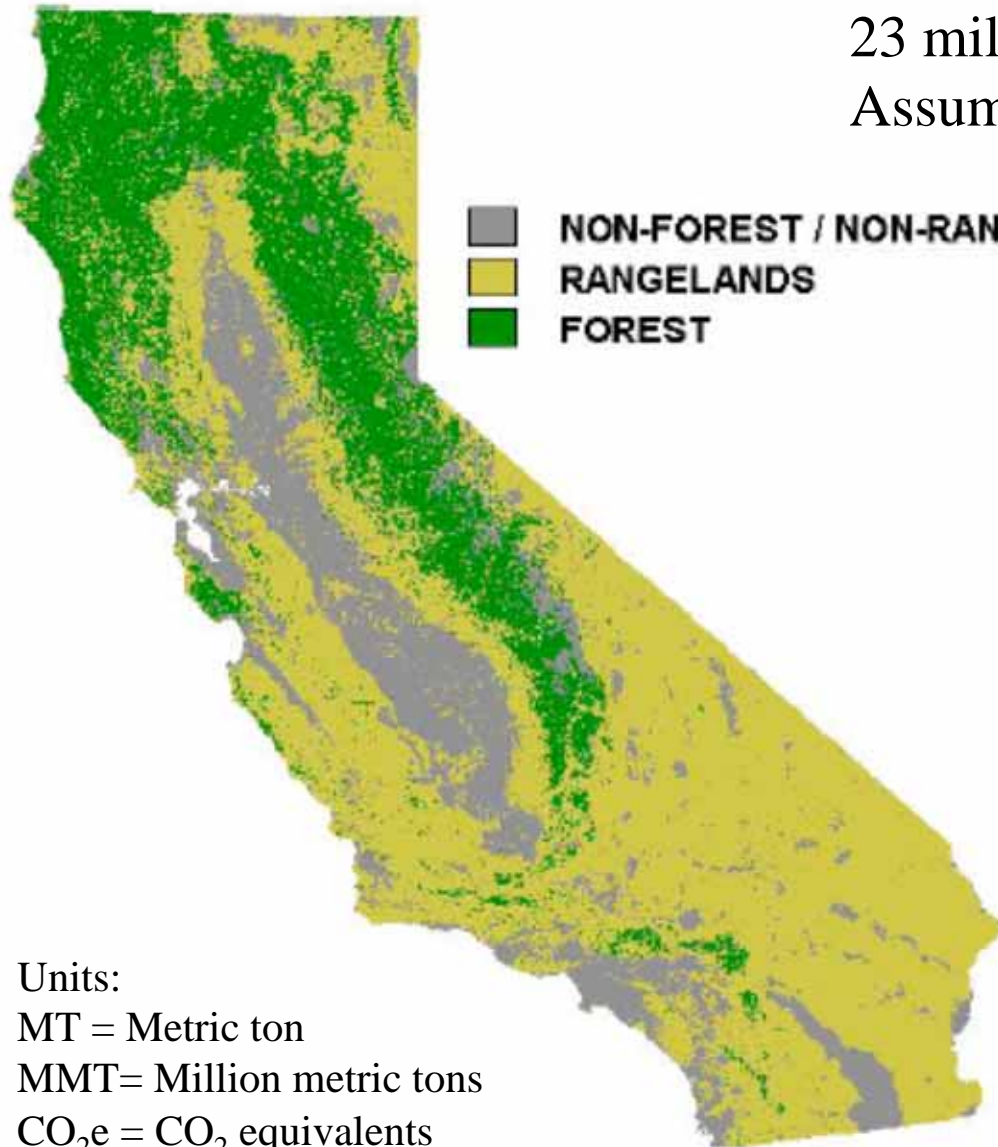
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• **Transportation emits ~188 MMT CO₂e/yr**

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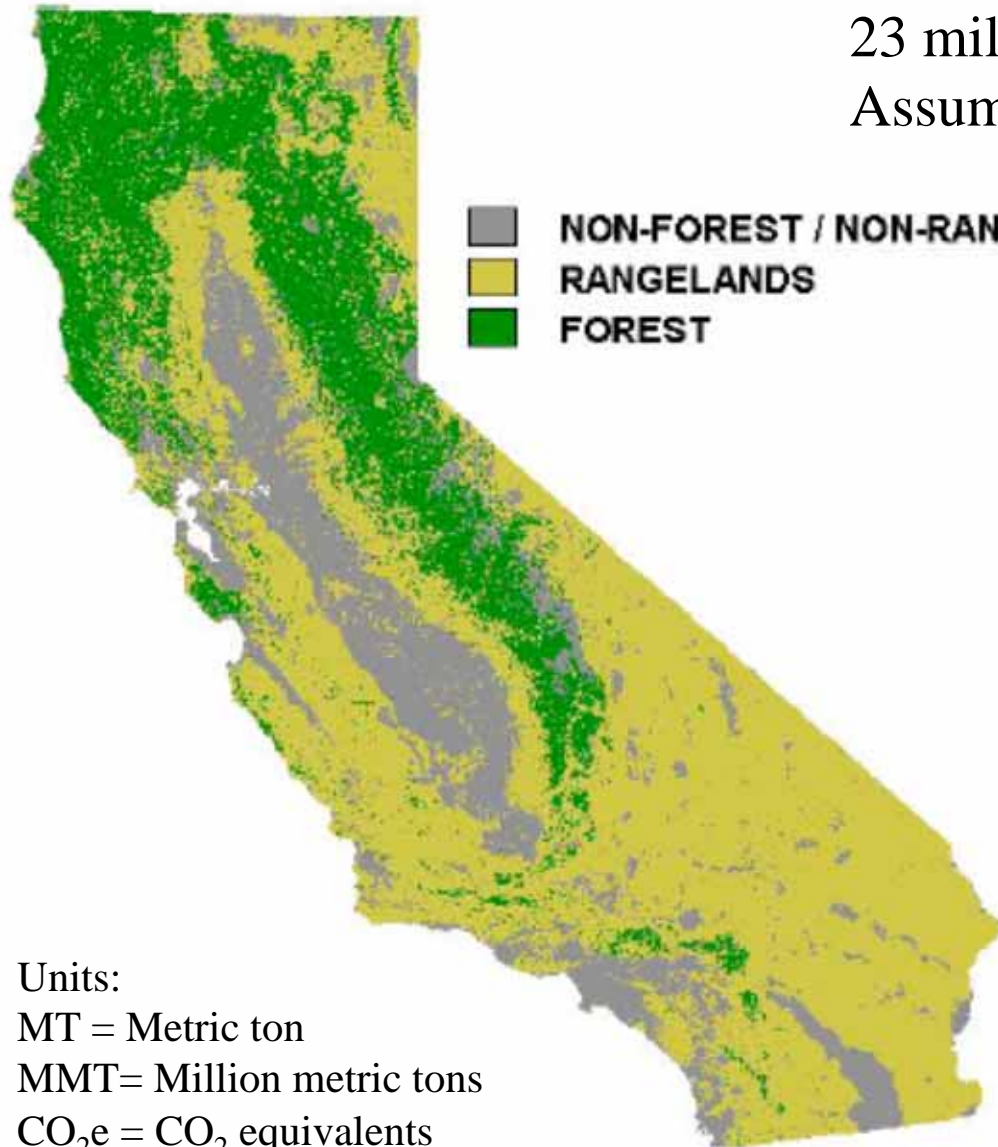
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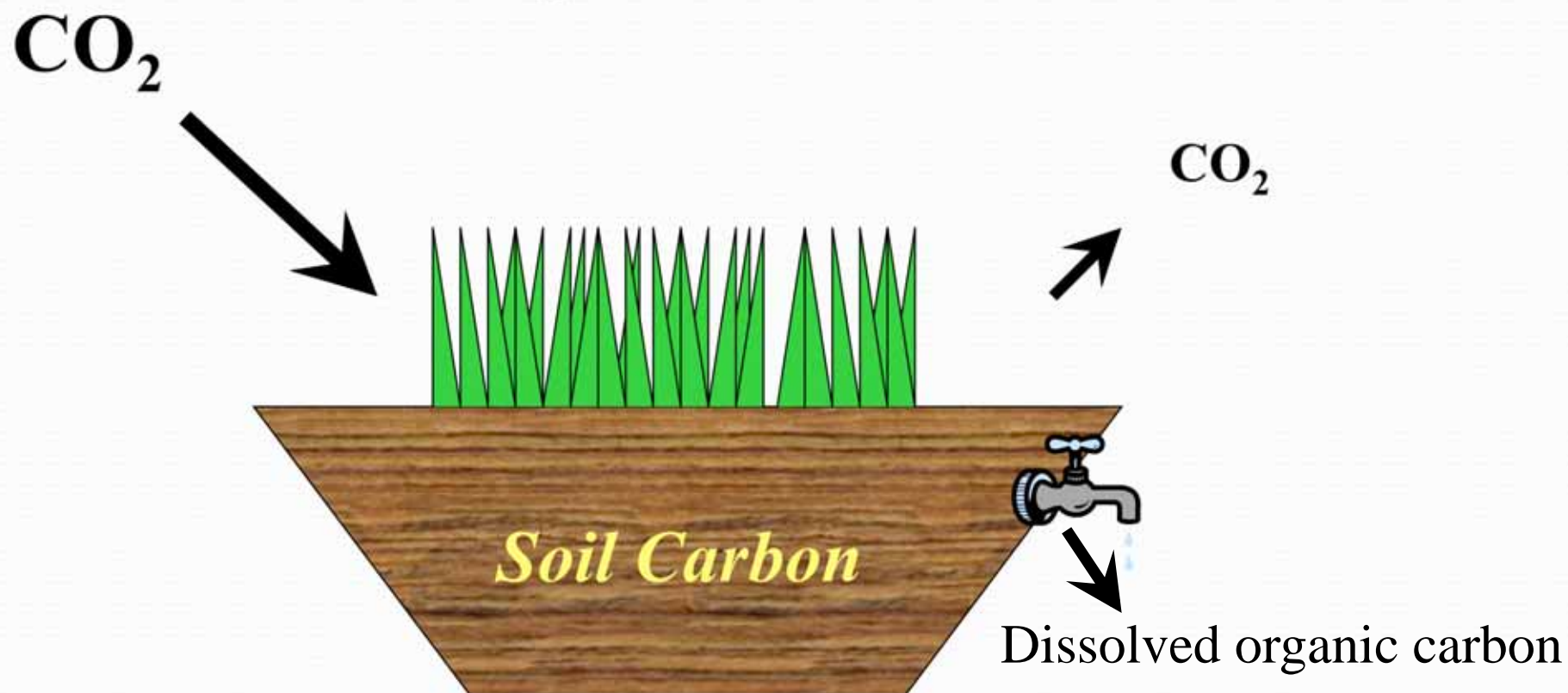
At a rate of $5 \text{ MT C ha}^{-1} \text{ y}^{-1}$
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- **Livestock ~ 15 MMT CO₂e/y**
- **Commercial/residential ~ 41 MMT CO₂e/y**
- **Transportation emits ~188 MMT CO₂e/yr**
- **Electrical generation ~109 MMT CO₂e/y**

Units:
MT = Metric ton
MMT= Million metric tons
CO₂e = CO₂ equivalents
MT=Mg=Metric ton

How does soil carbon sequestration work?

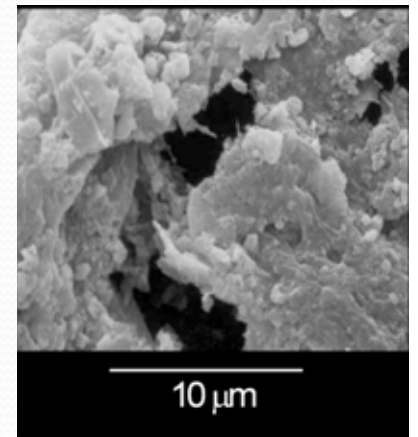
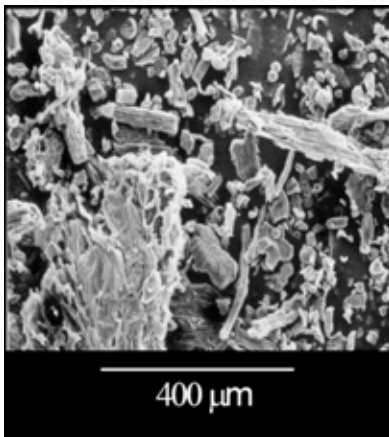
Carbon Inputs > Carbon Losses




Carbon sequestration is a win-win situation:

Carbon sequestration in pastures and rangelands increases:

- **Fertility**
- **Water holding capacity**
- **Soil stability**
- **Sustainability**
- **Productivity**



The deeper the carbon the longer it stays around

		Organic C content	Proportion of C in profile	Relative Residence time
	0 cm	High	30-50%	Short
	10 cm			
	30 cm	Low	20-30%	Intermediate to long
	100 cm	Very low	10-30%	Long

Marin Carbon Project

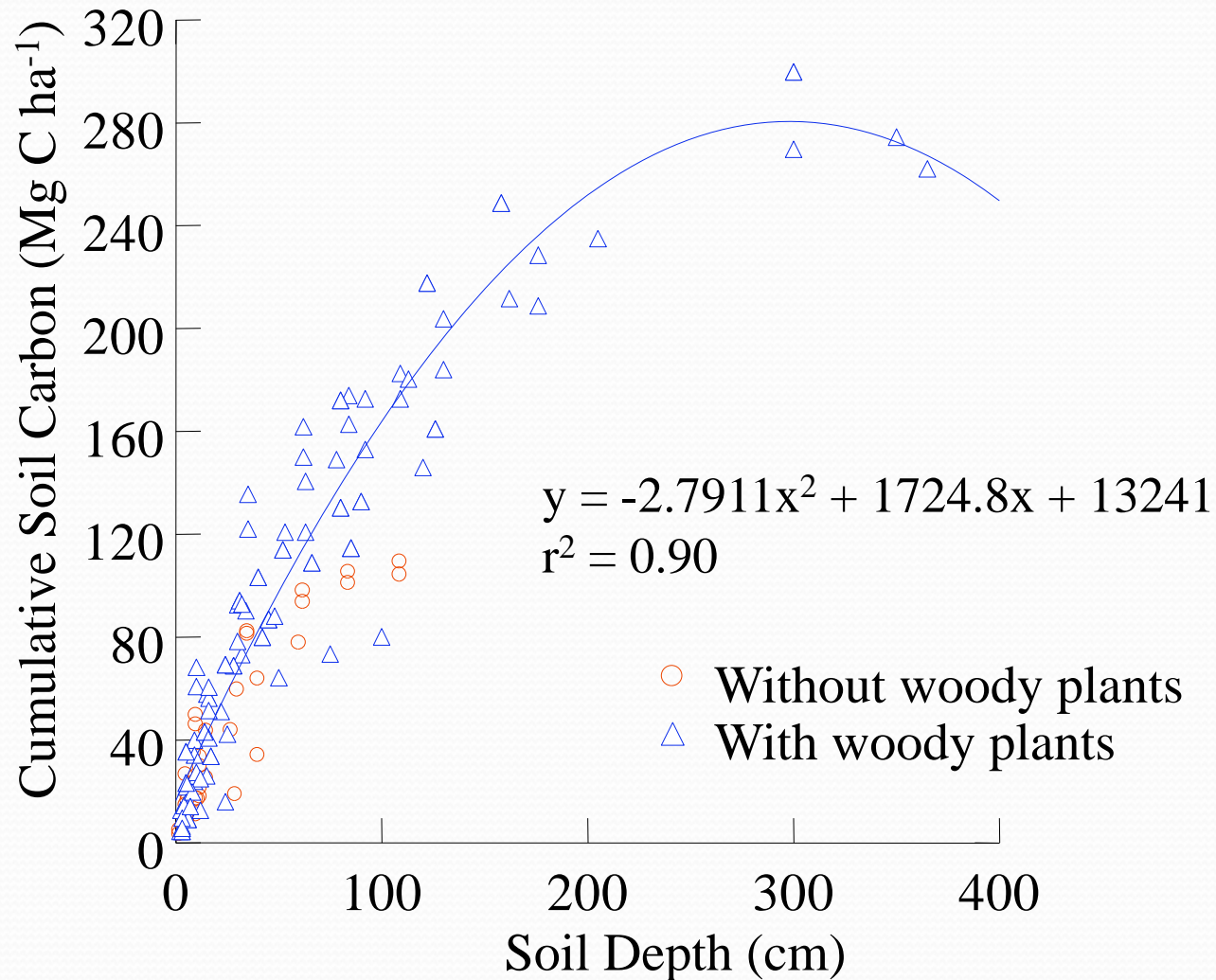
**(UC Berkeley and Davis, Stakeholders, Resource Conservation District,
UC Extension, Marin Agricultural Land Trust, Marin Organic)**

Phase I

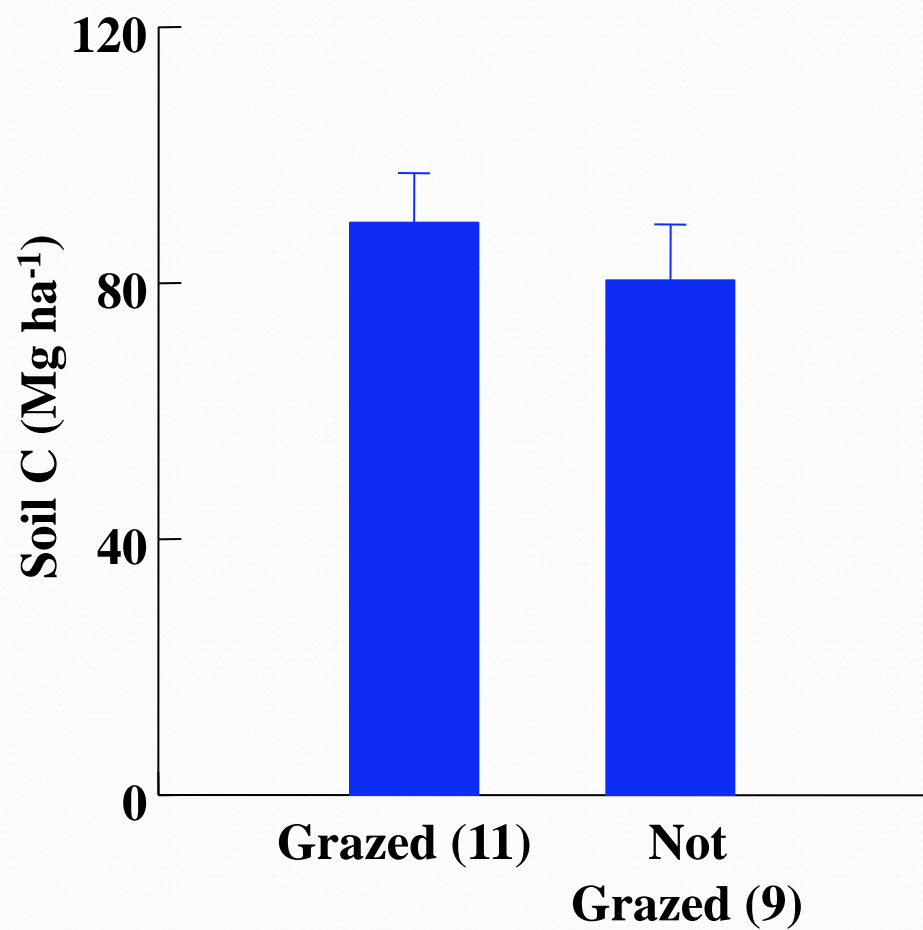
Is it possible to sequester carbon in rangeland soils?

- 1. Determine the amount of carbon in California's rangeland soils; examine potential relationships with climate, soil type, management, and cover type.*
- 2. Determine the amount of carbon in Marin and Sonoma County's rangeland soils; explore relationships with soil type, management, and cover type.*

Soil carbon pools increase to 1-2 meters depth in California rangeland soils.

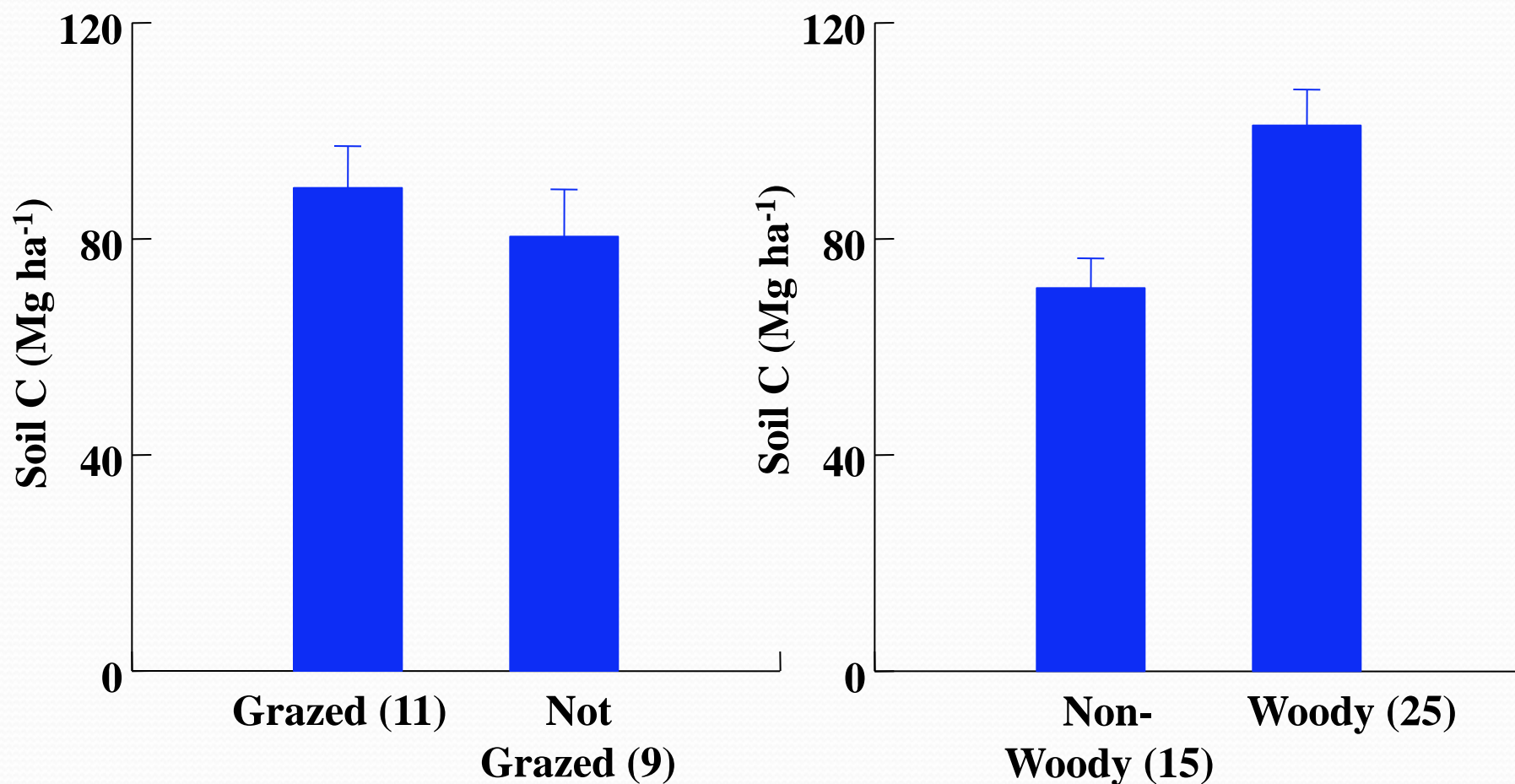


Grazing had no detectable impact on soil C pools

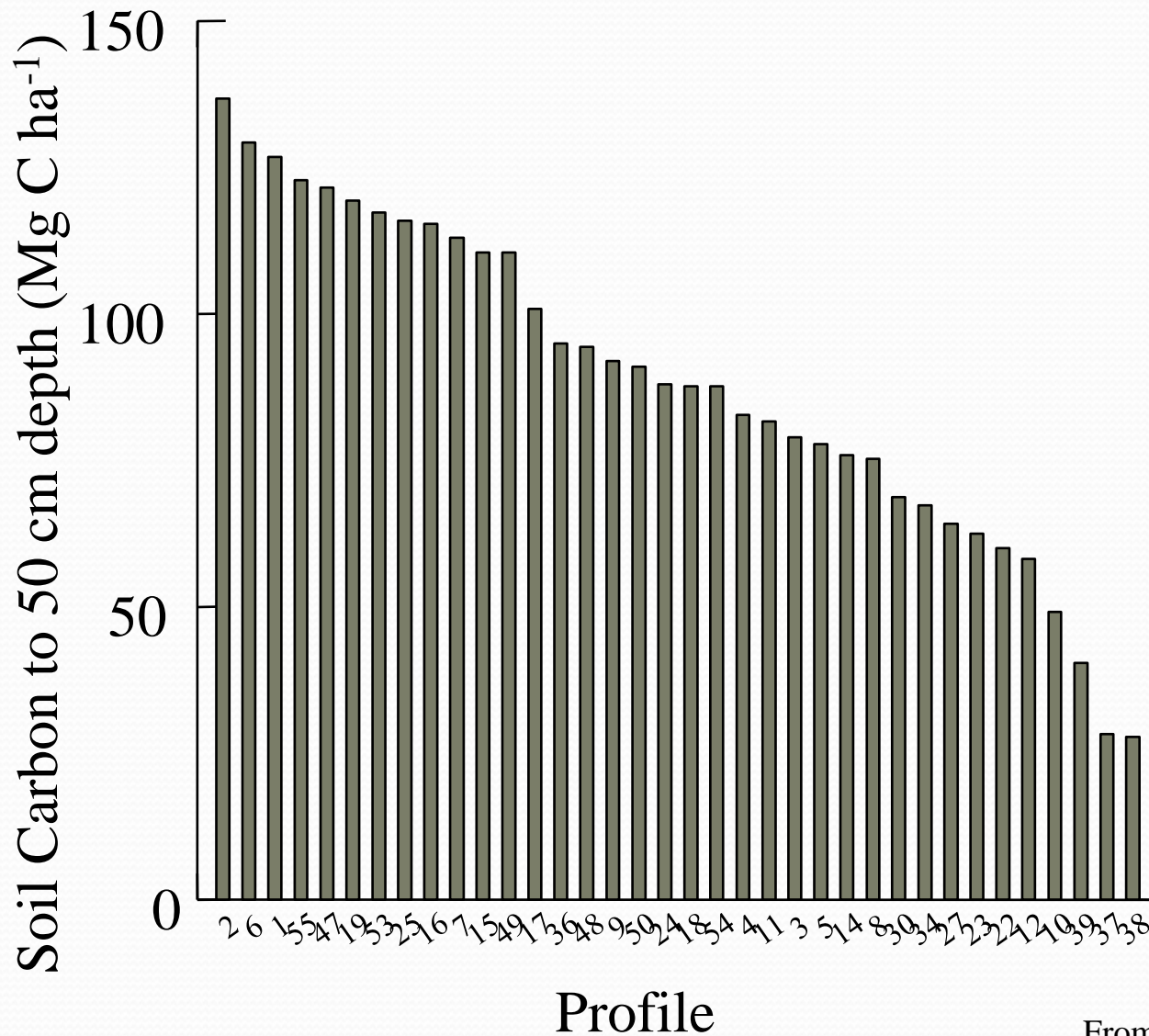


Grazing had no detectable impact on soil C pools

Woody plants increased rangeland soil C by approximately 30%



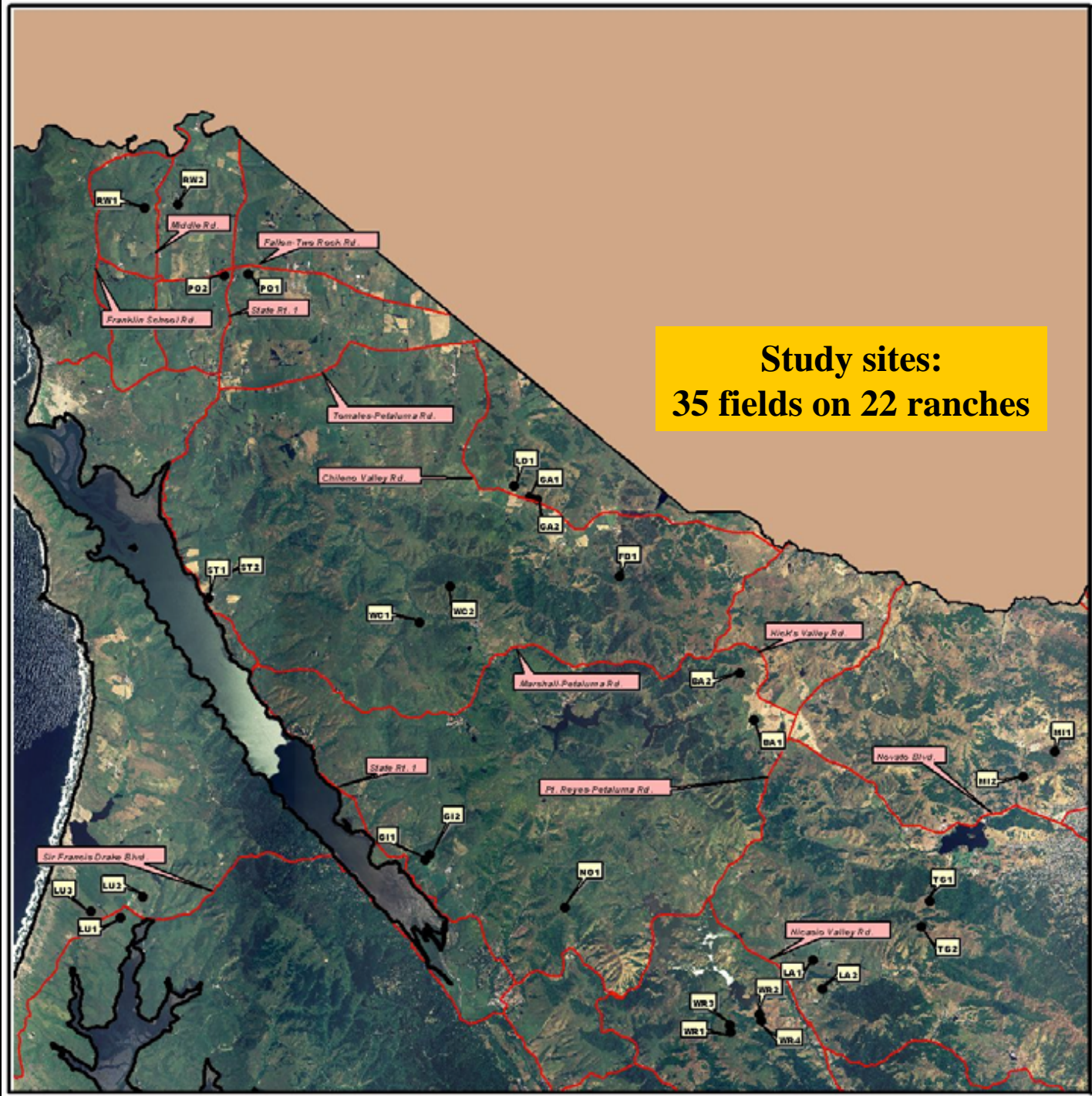
- Large range in soil carbon pool size
- Considerable soil C storage capacity



From Silver et al. submitted

How much carbon is there in Marin and Sonoma rangeland soils?





**Study sites:
35 fields on 22 ranches**

Marin and Sonoma Counties



1 inch = 14,000 feet

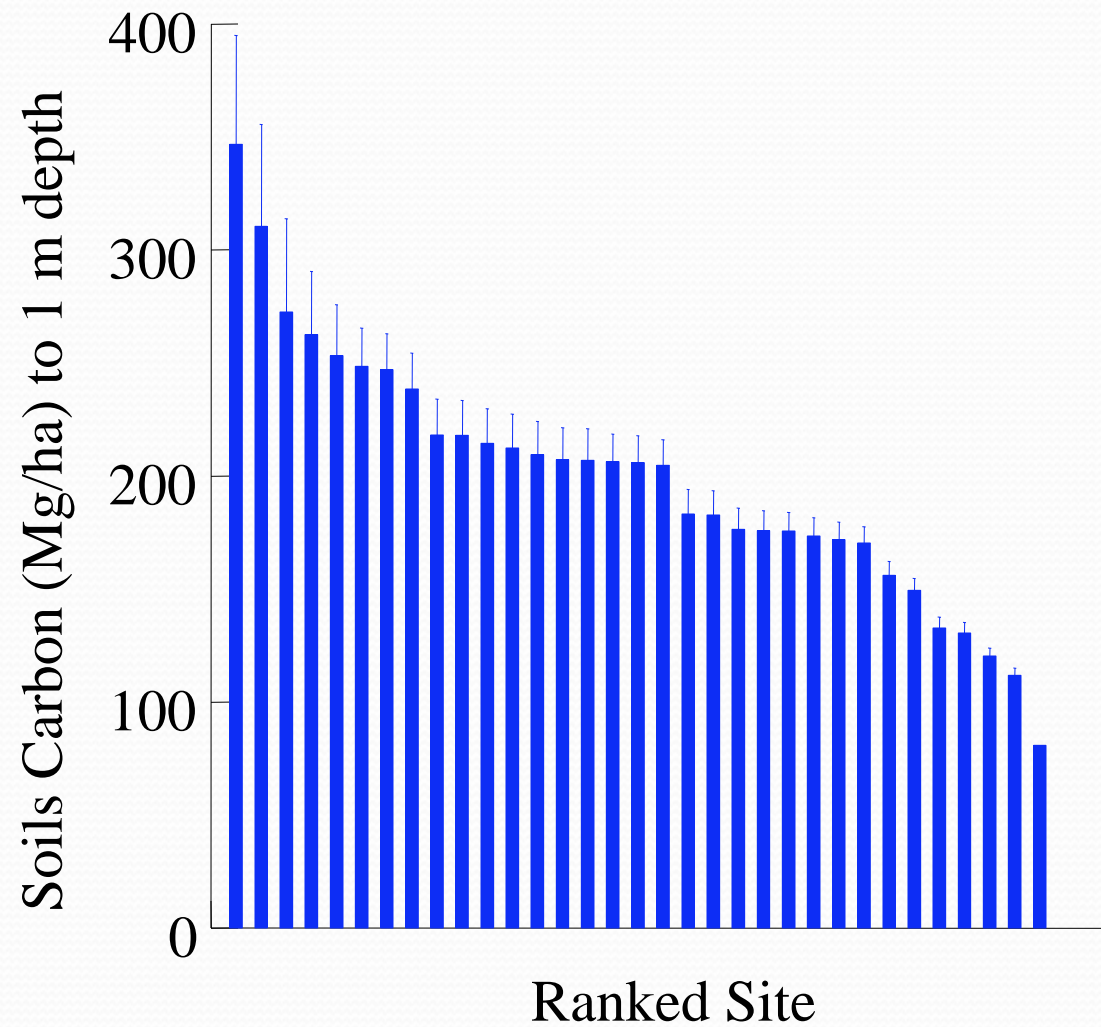


MARIN AGRICULTURAL LAND TRUST

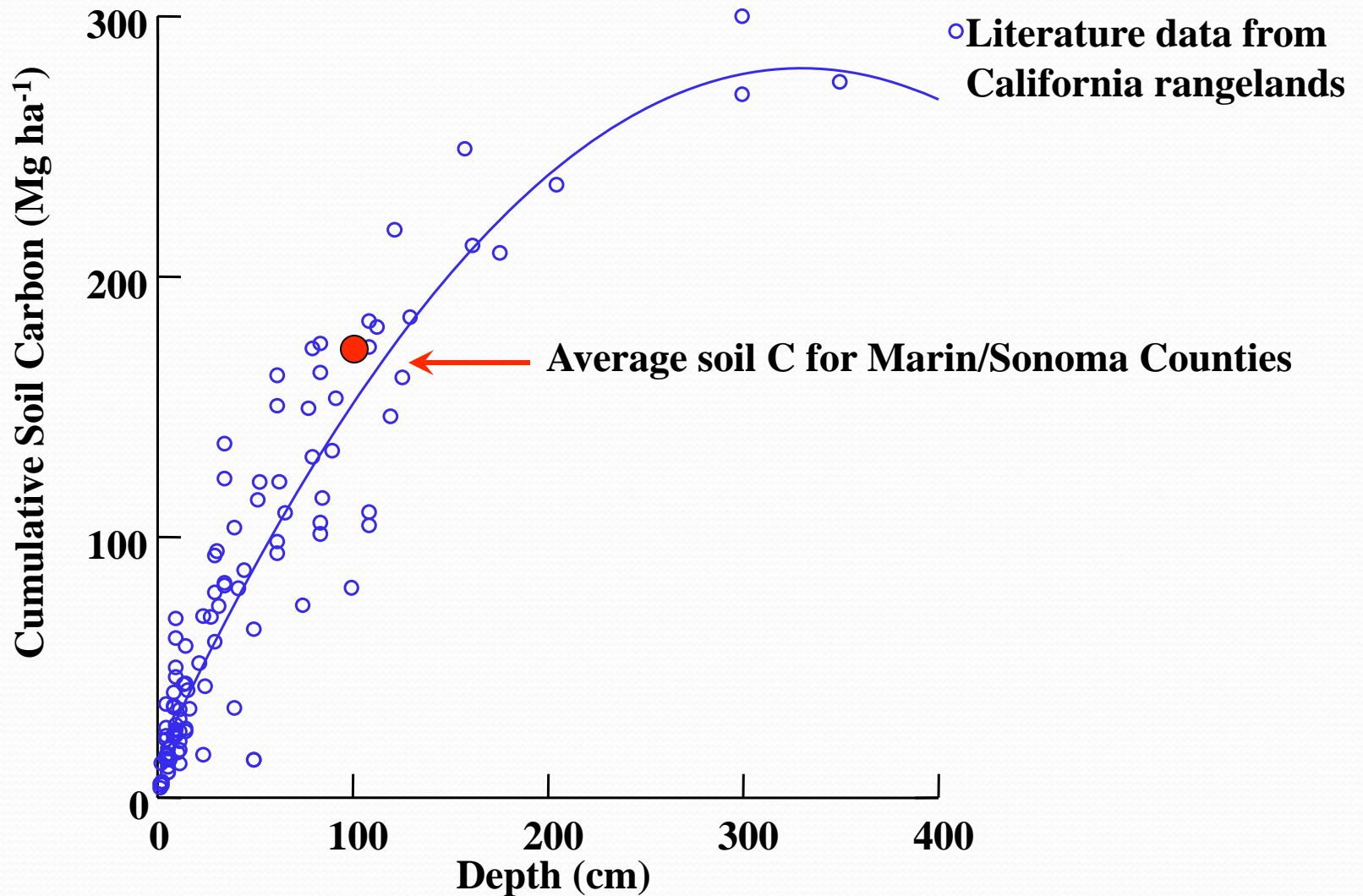
Map prepared by Marin Agricultural Land Trust
February 2008

Sample locations approximate and should be field verified

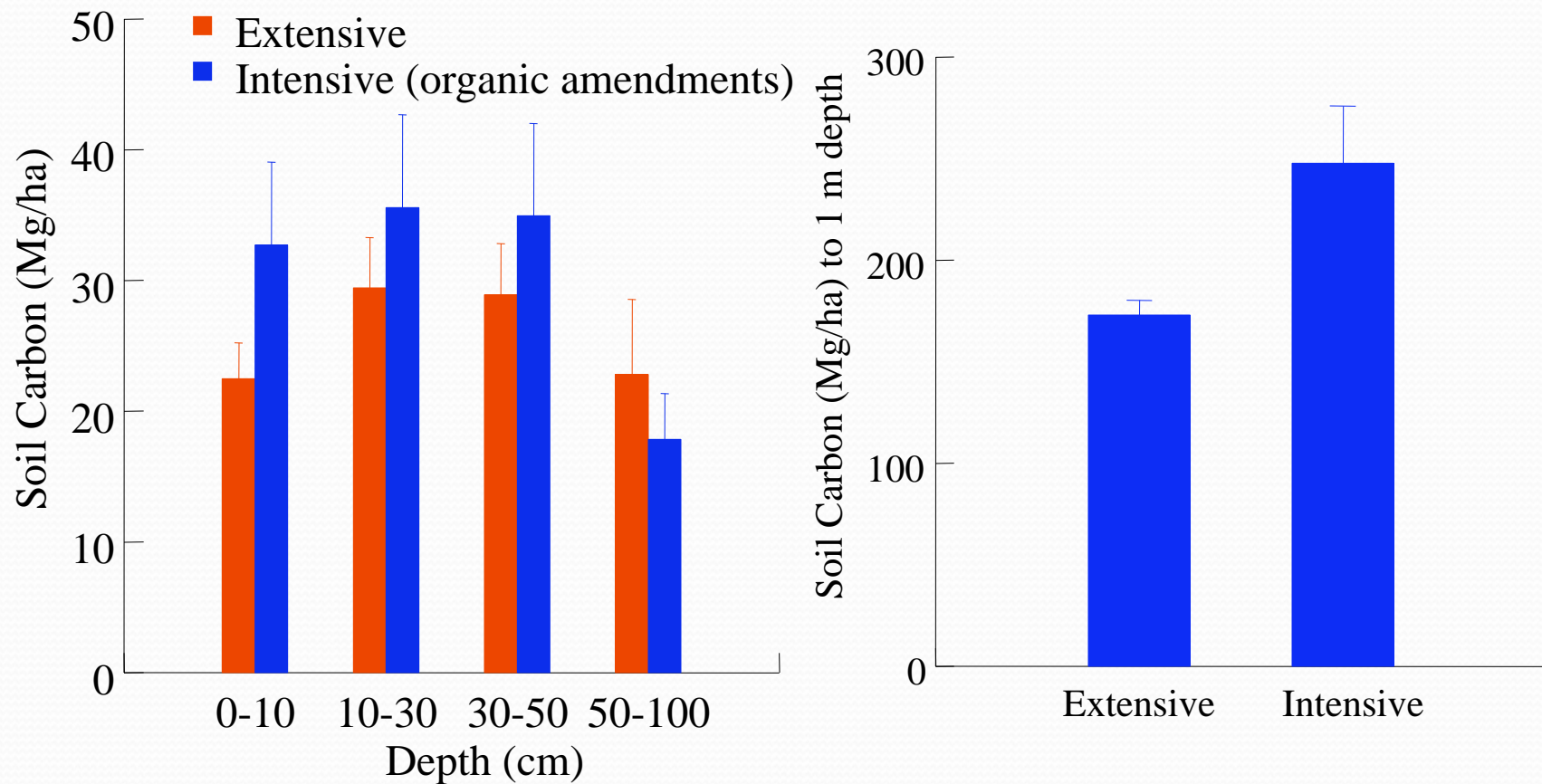
The regional analysis also showed a wide range in soil C pools



On average Marin soils appear to be in the mid range of California rangelands



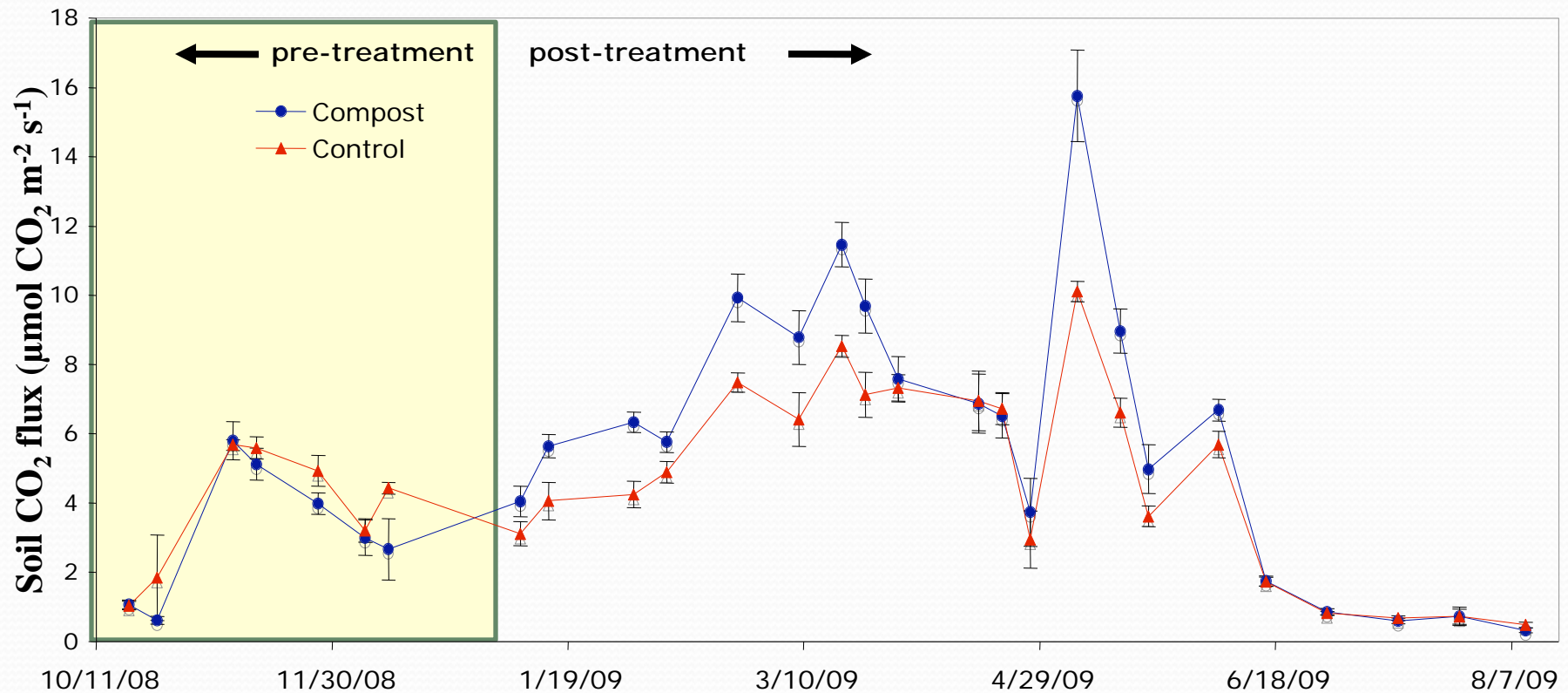
Organic amendments increased soil carbon by 50 Mg C ha⁻¹ in the top meter of soil



- **Organic amendments (compost) to grazed rangelands (Nicasio and Browns Valley)**
- **Followed CO_2 , N_2O , and CH_4 fluxes and aboveground net primary production**

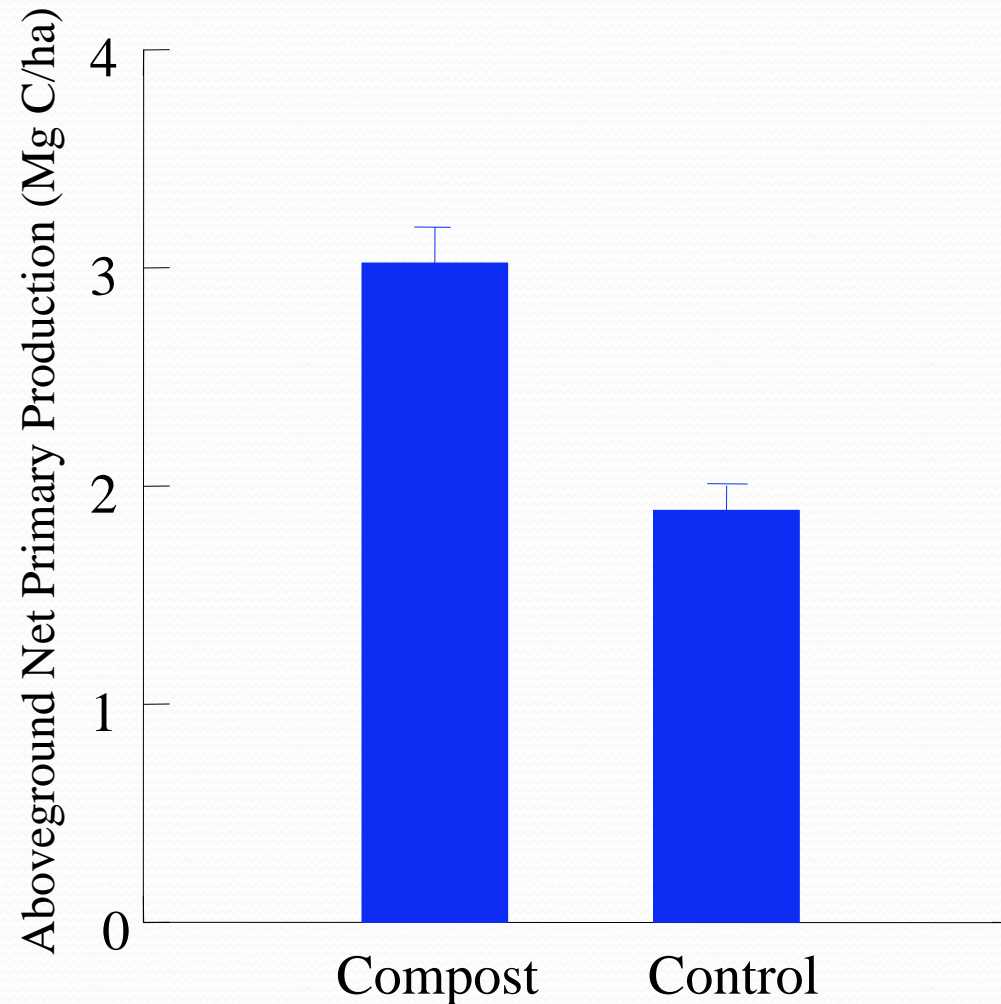


Compost additions led to slightly greater soil CO₂ emissions



No significant effect on nitrous oxide and methane emissions

Compost significantly increased plant and forage production



Net gain at the field scale = 14.8 Mg C/ha (54 Metric tons of CO₂eq)

The Next Steps

- 1. Life Cycle Analysis: what is the full greenhouse gas accounting of these management activities?**
- 2. Grazing Management: can grazing management alone increase soil carbon storage?**
- 3. Plant Community: What happens to it and can we encourage native perennial grasses through carbon farming?**
- 4. Translating Science into Implementation and Policy: verification, protocols, additionality**



Summary

Rangelands have considerable potential to sequester atmospheric CO₂

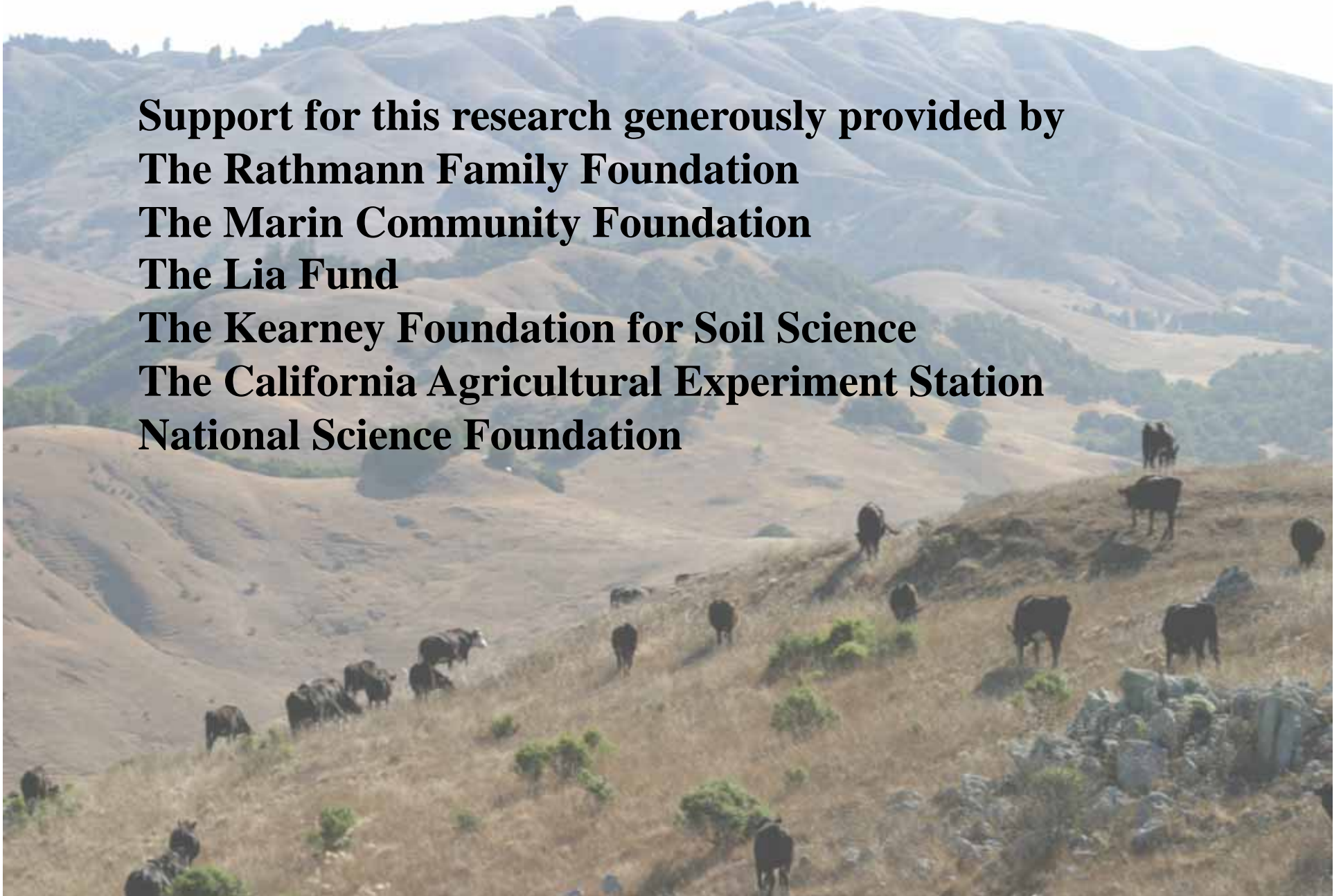
The co-benefits are large and the risks are relatively low

Organic amendments or woody plant addition are potential strategies to increase carbon sequestration.

Research needs include life cycle analyses, verification and protocol development, and optimization tools

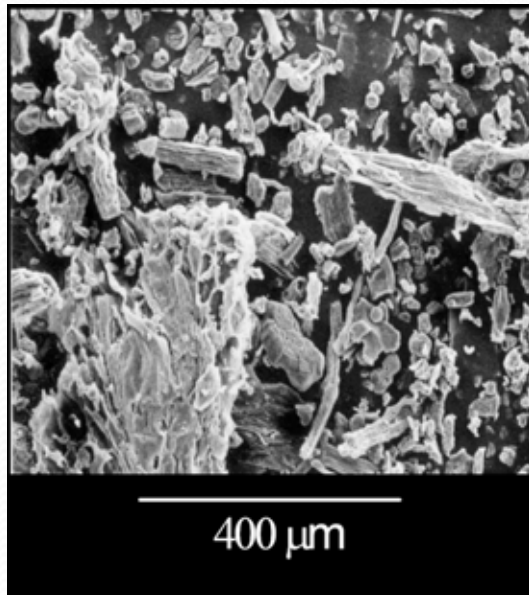
Thank you

**Support for this research generously provided by
The Rathmann Family Foundation
The Marin Community Foundation
The Lia Fund
The Kearney Foundation for Soil Science
The California Agricultural Experiment Station
National Science Foundation**

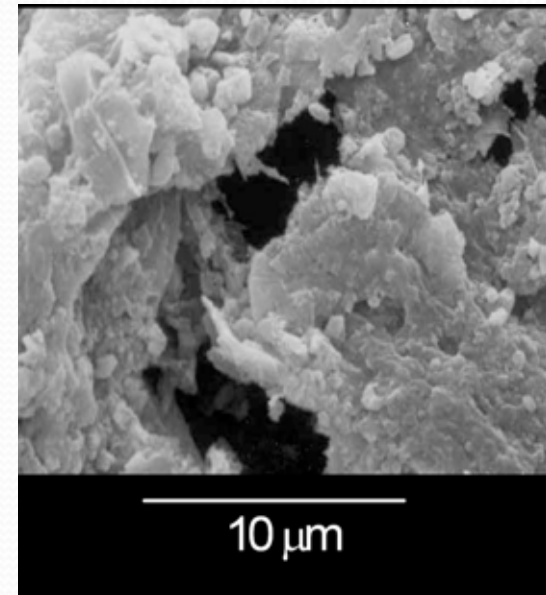


Not all carbon is created equal

Particulate material



Humus



Soil carbon is a continuum of material with different degrees of decomposition

Human activities have dramatically increased the atmospheric concentrations of greenhouse gases

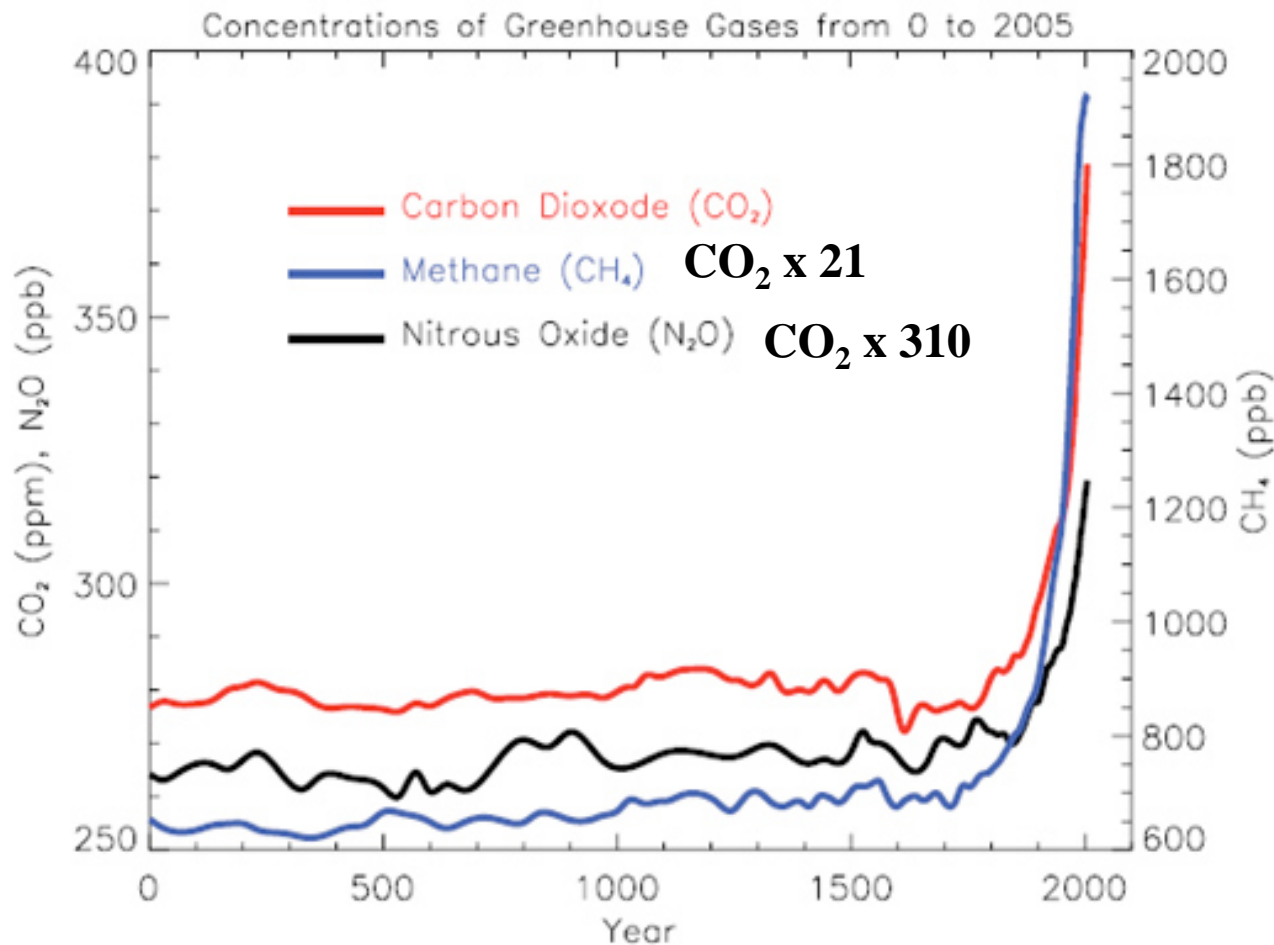
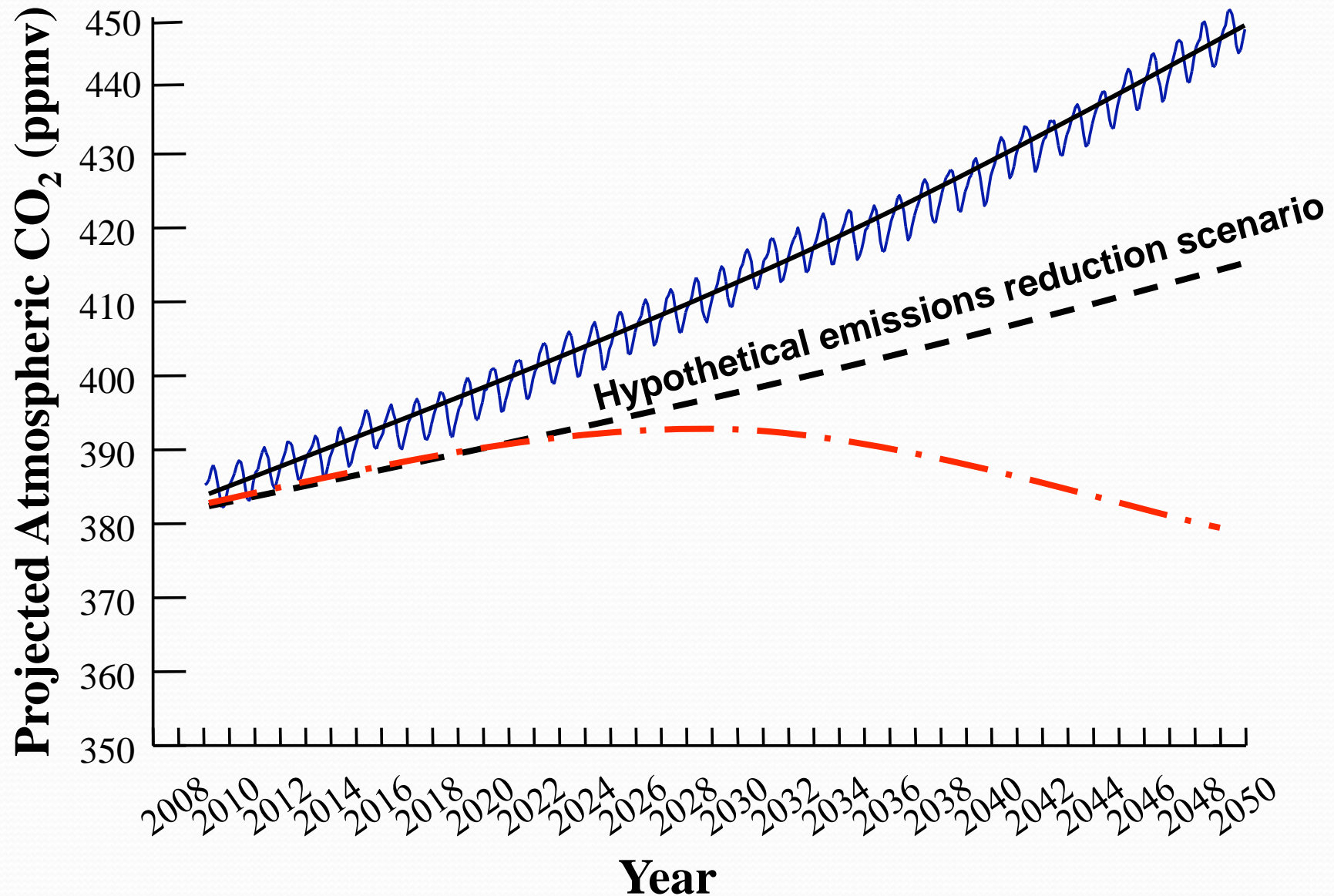


Figure 1. Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Increases since about 1750 are attributed to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion air molecules, respectively, in an atmospheric sample.

Reducing emissions alone will not mitigate climate change



Atmosphere 760

Global Gross Primary
Production and
Respiration

119.6

120.2

1.6

Changing
Land-Use

2.6

90.6

92.2

7.2

Fossil Fuel
Combustion and
Industrial
Processes

Vegetation
and Soils
2,300

Ocean
38,000

(Soils = 1600 Pg C)

Carbon Flux Indicated by Arrows: Natural Flux =  Anthropogenic Flux = 

Source: Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis*, Figure 7.3 and Table 7.1, (U.K., 2007).

